Design of Improved Economic Impact and Adaptation Studies

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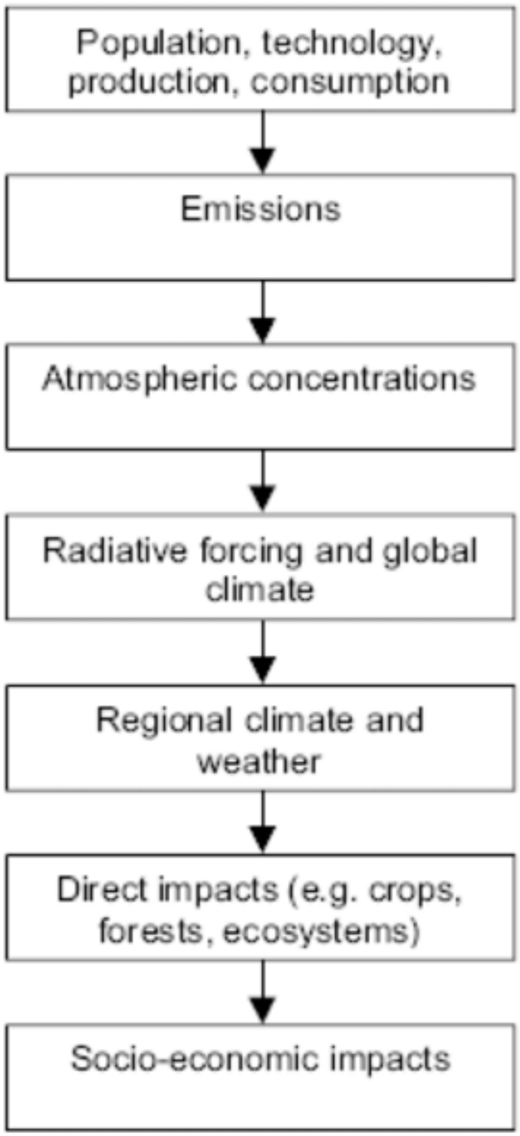
Modeling steps: from emissions to impacts



- All of the steps are marked by uncertainty and some degree of scientific disagreement.
  - For a given emissions scenario, different climate models yield different projections of temperature and precipitation.
  - Given a projected change in climate variables, different models use different damage/valuation functions and reach different conclusions regarding the economic cost.
- In fact, the disagreement among damage and cost functions is significantly larger than that among climate change projections.
- This is so for two reasons.
  - The climate modeling has been going on for longer and at a higher level of activity than the damage and cost modeling, and is therefore in a more mature state.
  - Damage estimation is inherently more complex: it involves a high level of spatial disaggregation and a wide range of biological, chemical, hydrological and physical phenomena, most of which are not yet well modeled.

Two key challenges

- Finer spatial disaggregation
- Finer probabilistic detail

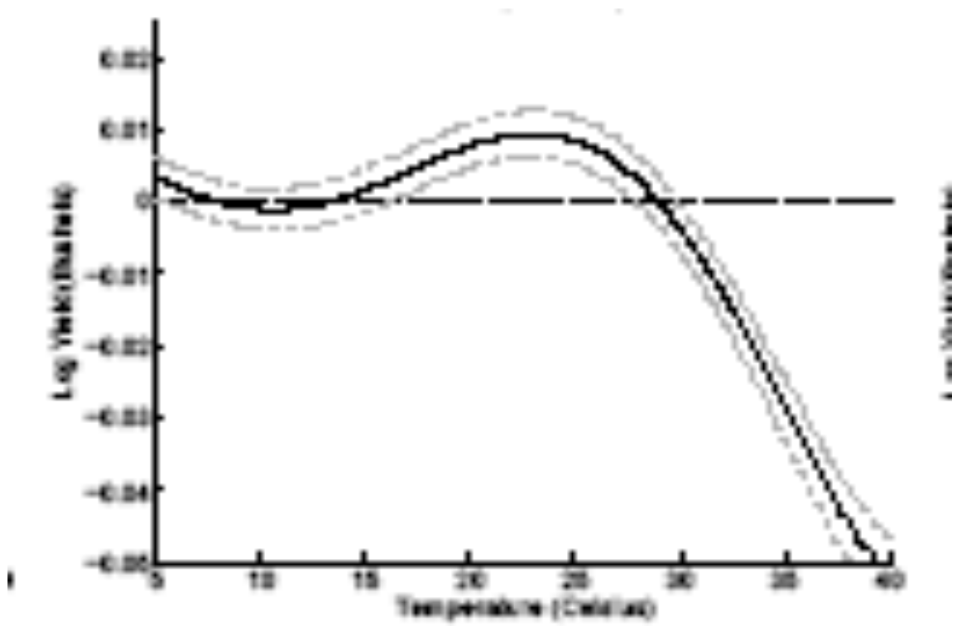
While economic valuation remains difficult, I put those two items at the top of the list.

Importance of spatial resolution

- The curse of the average! Spatial heterogeneity combined with a convex damage function means that use of broad spatial/temporal averages tends to systematically understate damages.
- All impacts, and all adaptation are local! For the purpose of understanding adaptation, need to match boundaries of jurisdictions involved.

Asymmetric Relation of Temperature and Crop Yield Schlenker & Roberts (2006, 2008, 2009)

- Relationship is distinctly asymmetric, fairly flat at first and then sharply declining beyond an upper threshold.
- It is *not* symmetric as assumed by Mendelsohn, Nordhaus & Shaw.



Jurisdictional fragmentation

- Hundreds of water districts, each with its own particular source of supply, water rights, conveyance system, cost structure, and allocation system. Many flood control and levee districts.
- Land use planning similarly fragmented.

Each entity needs to be able to see itself in the impact assessment.

Units of observation

- As much as possible, the unit of observation for our economic impact and adaptation analysis needs to be the jurisdictional unit – e.g., water district, flood district, etc.

Distributional implications

- Climate change is a massive machine for the spatial re-distribution of income and wealth.
- Distributional issues matter greatly in the real world. The economic convention of ignoring distribution and looking just at the aggregate net impact is a grave mistake.
- This is an additional reason for spatial disaggregation

Bringing risk & risk aversion into the picture

- From the physical, economic and behavioral perspective, the most important component of impacts is associated with extreme events – the crossing of thresholds.
- In many cases these are not diversifiable risks.
- Hence, there is likely to be some significant degree of risk aversion associated with those events.
- This has not been factored into most existing economic analyses. It need to be factored in going forwards.

Risk aversion

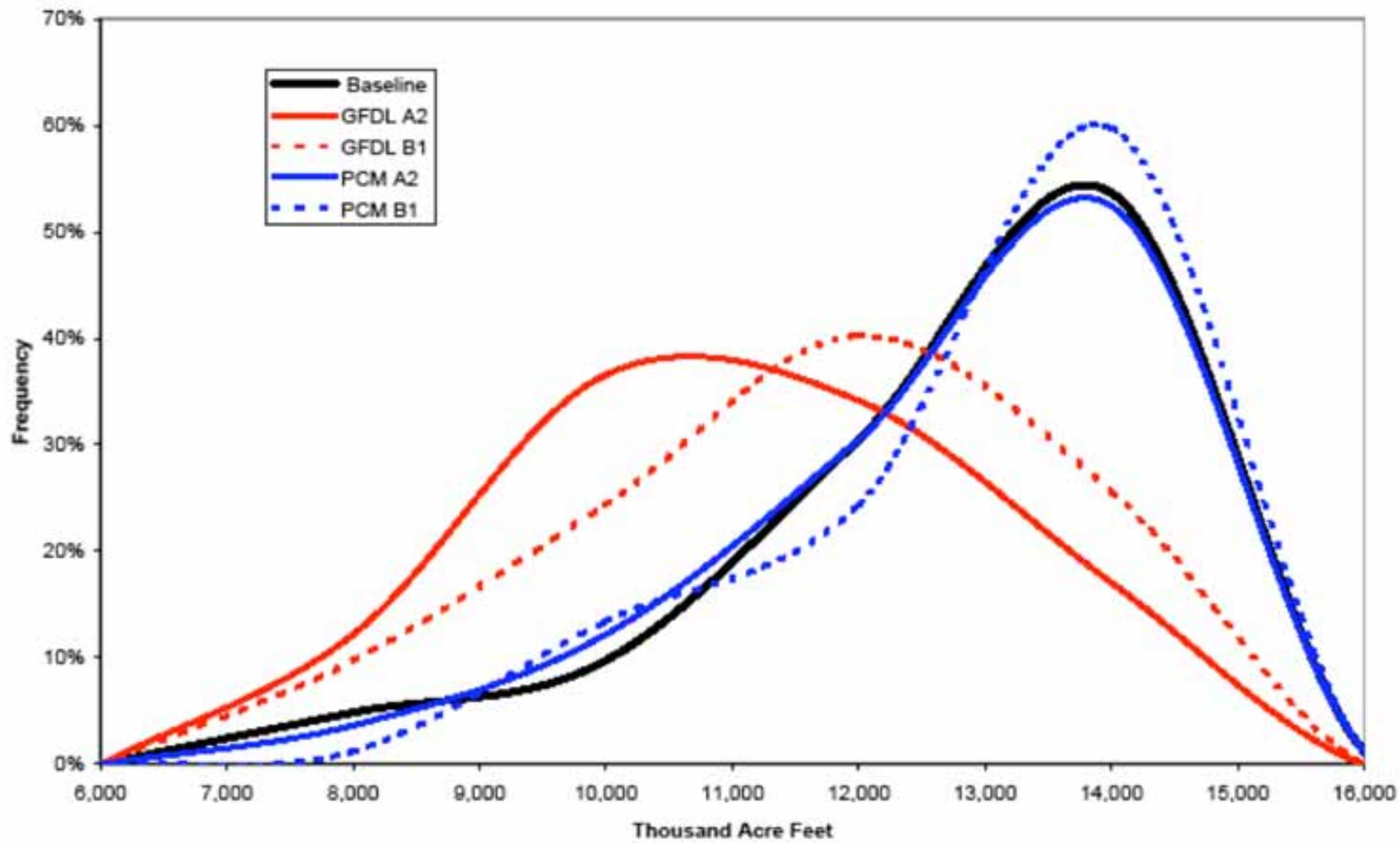
- For a decision-maker who is risk neutral, outcomes can appropriately be framed in terms of expected value.
- For a d-m who is risk averse, a negative risk premium needs to be attached to the outcome, reducing the expected value. The risk premium increases with (a) the magnitude of risk, as measured by the variance, and (b) the degree of risk aversion.
- For a d-m who is risk loving, a positive risk premium needs to be attached to the outcome, increasing the expected value.
- I assume here that risk aversion is what is called for.

- To account for risk aversion, need to:
  - Measure the degree of risk aversion among relevant decision makers
  - Measure the degree of risk (variance of outcomes).
- Where outcomes are multidimensional, there are multivariate concepts of risk aversion (though they raise some technical complications).

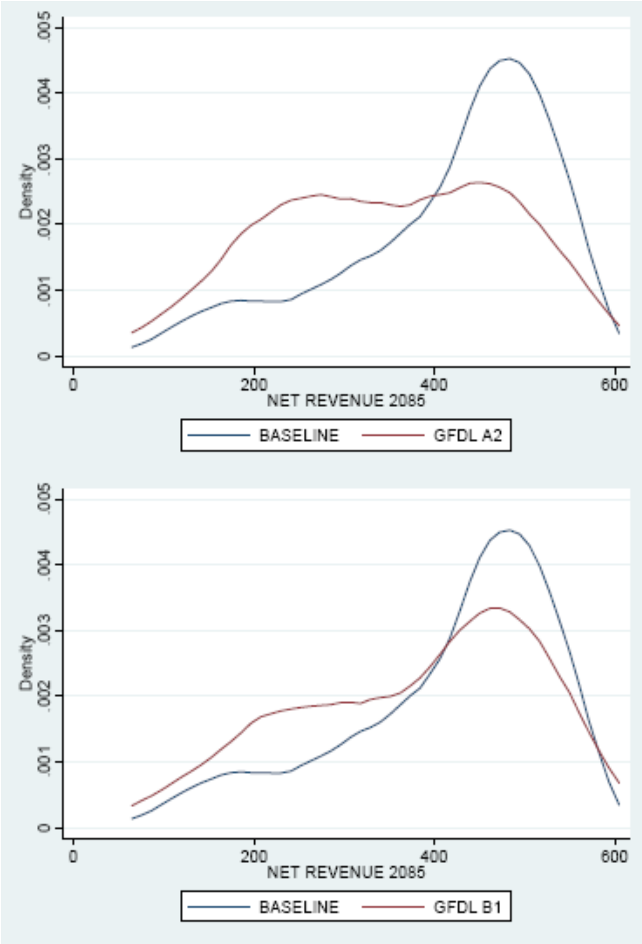
Downside risk

- This is a modification of the conventional theory of risk aversion.
- It is based on the notion that there is some asymmetry in risk attitudes towards outcomes.
- Downside outcomes (defined relative to some point) are weighed more heavily than upside outcomes.
- The concept was first applied in the financial literature in the 1970s – going broke is viewed differently than making a profit.
- It is likely to apply to many physical outcomes of climate change – e.g., asymmetry between having too little water and having too much.

Annual deliveries to Central Valley agriculture, 2085



Net revenue from Central Valley agriculture, 2085



Annual net revenue ($ million)

	MINIMUM	MAXIMUM	MEDIAN	MEAN	STANDARD DEVIATION
BASELINE	107	562	456	415	113
GFDL A2	83	516	326	314	122
GFDL B1	95	520	384	349	122
PCM A2	132	548	442	397	113
PCM B1	114	543	464	413	109
			LOSS COMPARED TO BASELINE		
GFDL A2			130	101	
GFDL B1			72	66	
PCM A2			14	18	
PCM B1			-8	2	

The mean-risk model

(6) Maximize the mean and minimize the risk.

One formulation represents this through a weighted objective function

(6a) Maximize $\mu_x - \lambda R_\alpha(x)$

where μ_x is the mean of $f(\cdot)$, $R_\alpha(x)$ is the downside risk associated with $f(\cdot)$, and $\lambda > 0$ is a weighting factor reflecting the relative preference for mean versus downside risk avoidance.

Mean-risk models such as (6) and (6a) have been rationalized in terms of stochastic dominance and expected utility maximization. For $\alpha = 2$, Bawa (1978) related the mean-target-semi-variance rule to third order stochastic dominance. He proved that one distribution $f(x)$ is preferred to another distribution $g(x)$ for all von Neumann-Morgenstern utility functions with positive first derivatives, negative second derivatives, and positive third derivatives (i.e., decreasingly risk averse)—which is the condition for third order stochastic dominance—if the mean of $f(x)$ is at least as large as that of $g(x)$ and the target semi-variance at least as small, with strict inequality for some value of T.

Fishburn (1977) also identified the von-Neuman-Morgenstern utility function that is congruent with the mean-α-order lower partial moment model. He showed that this utility function takes the form

$$(7) \qquad u(x) = \begin{cases} x & \text{for all } x \geq T \\ x - k\,(T-x)^{\alpha} & \text{for all } x \leq T \end{cases}$$

where k is a positive scaling constant. Fishburn showed that $\alpha < 1$ implies (downside) risk seeking behavior, while $\alpha > 1$ implies (downside) risk aversion; $\alpha = 1$ implies (downside) risk neutrality. He showed how to calibrate α and k for a given value of T. The parameter

α can be calibrated by having a decision maker choose between some particular gambles and a sure thing. It can also be calibrated from observed data on choices between gambles. Based on a review of some empirical evidence about the behavior of decision makers in the face of risk, Fishburn suggested a value of $\alpha = 4$; that value is used below. The value of k can be determined by observing that, with (7), one obtains

$$(8) \qquad k + 1 = \frac{u(T) - u(T-1)}{u(T+1) - u(T)}\,.$$

With Fishburn's utility function (7), the formula for expected utility is

(9) $$E\{u(x)\} = \mu_x - k\,R_\alpha(x) \ .$$

Given a probability distribution of outcomes, $f(\cdot)$, and a utility function, the *certainty equivalent* of $f(\cdot)$ is defined to be the quantity x_0 such that $u(x_0) = E\{u(x)\}$. With (7), assuming that $x_0 > T$, the certainty equivalent is given also by the right-hand side of (9):

(10) $$x_0 = \mu_x - k\,R_\alpha(x) \ .$$

Thus, expected utility maximizing behavior in the face of risk calls for adjusting the expected payoff by a downside risk premium, the second term on the right-hand side of (10). Risky ventures should be judged on the basis of this downside-risk adjusted expected payoff.

A possible alternative to (10) and (12) is a mean-risk criterion function of the form:

(13) $$\hat{x} = \mu_x - RN_\alpha(x) \ .$$

This is not rationalized by a specific utility function, but it could be used as a practical criterion for evaluating risky prospects in the spirit of (6a). This criterion will be used

Application of downside risk

We now apply the concept of downside risk aversion as reflected in the criterion (13) to the impact of the climate change scenarios on both agricultural and urban water users. Following the finding by Fishburn (1977), we set $\alpha = 4$.

In the case of Central Valley agriculture, we define the outcome, x, to be the annual net revenue from farming in the Valley, and we set $T = 0$; thus, downside risk refers to the prospect of negative net revenue from farming in the Central Valley.

Downside risk-adjusted impact

CENTRAL VALLEY AGRICULTURE ANNUAL NET REVENUE 2085 ($ million)			
	MEAN	DOWNSIDE RISK FACTOR	ADJUSTED VALUE
BASELINE	$415	$132	$283
GFDL A2	$314	$178	$136
GFDL B1	$349	$163	$186
PCM A2	$397	$130	$267
PCM B1	$413	$126	$287
	LOSS COMPARED TO BASELINE		
GFDL A2	$101	$46	$147
GFDL B1	$66	$31	$97
PCM A2	$18	-$2	$16
PCM B1	$2	-$6	-$4

Implication

- For GFDL consideration of downside risk increases the estimate of loss by about 50%.
- For PCM, consideration of downside risk reduces the estimate of loss.